Space Weather Technical Forecast

Issued on Friday, 15 September 2023 at 13:04 Local

This technical forecast provides a four-day assessment of space weather events. The probabilities stated below are for reaching or exceeding the given levels. For more information about space weather impacts please see the Met Office Space Weather Scales https://www.metoffice.gov.uk/weather/learn-about/space-weather/uk-scales

Space Weather Forecast Headline: G2 Likely late UTC day of Saturday into Sunday. Chance of further G1 Monday. Chance R1 throughout. Possible further CME awaiting imagery.

Analysis of Space Weather Activity over past 24 hours

Solar Activity: Solar activity recorded at GOES16 and 18 has been Moderate in the past 24 hours. There are now up to eight sunspot regions on the disc, and the growth of a Mount Wilson delta spot in one of these - AR3429 - was strongly tied to an increase in the cadence and magnitude of observed flares, with these peaking with an M2.4 at 14/2126UTC, having earlier recorded an M1.9 at 14/1931UTC. Initially the trend in this group was of proliferation of spots, however this later eased as the Mt Wilson Delta developed in its centre. Other sunspots on the disc were generally both simpler and in decay, including all of the remaining three larger bipolar groups, AR3425, AR3430 and AR3423.

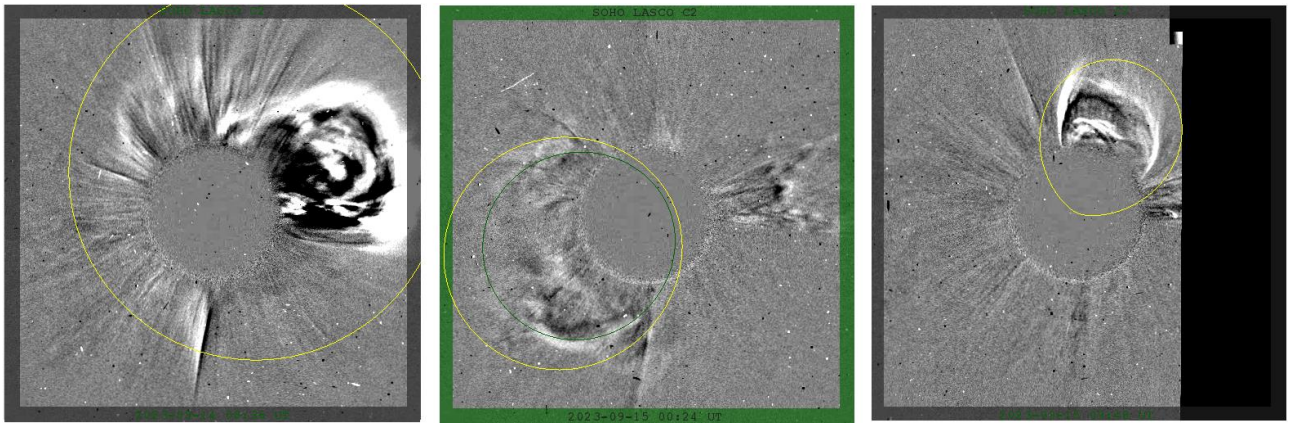

Figure 0: Trio of CME candidates seen in SOHO Lasco C2 difference imagery in the past 30 hours – from left to right: M1.4 northwest filament CME 14/0745UTC; M2.4 AR3429 CME 14/2126UTC; possible northwest quadrant disappering filament CME 14/2130UTC. The first two carry Earthbound components, the third is under review. The yellow ellipse cone positions are indicative of the feature and not fits to the ejecta.

There is a large filament lying to the north of the most active sunspot group, AR3429 in the northeast quadrant. This is perhaps therefore more prone to instability should large flares from the active region destabilise its southern end in its 30 degree plus span. Also of note with this feature is the fact that it is a very poor fit to the (HMIBC) magnetic neutral lines underlying it at present (Udaipur H-Alpha 15/0650UTC and HMIBC for same time) - it appears to lie wholly within a mainly negative magnetic polarity region, rather than on any boundary. The reason for this is uncertain, but is perhaps due to its altitude (chromosphere) relative to the source for the HMIBC signal (photosphere); else perhaps there are sharp gradients in the field orientation here; or perhaps the support for this feature is breaking down. Whatever the mechanism for its unusual presentation, this is a feature to monitor.

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A visually weak CME seen heading south and east on late UTC evening coronagraph imagery has an uncertain attribution, however may be linked to the largest flare of the period, and AR3429. This has been modelled and shows a tentative side lobe hit in the UTC morning of Monday 18 September. The strongest evidence found for this CME is AIA304 imagery in the hours following the flare, with an apparent helicoidal dark emission seen heading slightly southward from the vicinity of AR3429. There was a near-simultaneous large disappearing filament observed from the northwest quadrant in the same imagery. This may be tied to an apparently northward-directed slow CME in the early hours of the current UTC day - to be confirmed pending further imagery.

Solar Wind / Geomagnetic Activity: Solar wind parameters, as measured by DSCOVR (as well as ACE and STEREO A) near L1, were perhaps most indicative of a possible CIR that did not fully evolve into its associated fast wind - this may be the result of skirting the southern limits of CH44/+, although the phi angle has remained negative (towards the Sun) throughout. ACE EPAM LEMS showed elevated low energy proton levels over this timeframe, and failed to show a sharp drop usually observed on commencement of any fast wind.

The solar wind speed rose from the high-400s of km/s into the low 500s to end the UTC day of 14 September, with a peak in solar wind density just shy of 30ppcc around 14/1900UTC. This came before a gradual trend downwards in both - with the observed speed reaching 450km/s, and the density more typical single-figures ppcc. The IMF peaked at a similar time to the density at 11nT, while the north-south component varied between +7 and -10nT, with an overall co-aligned bias that became most anti-aligned around the time of the density peak.

The net effect of the above solar wind measures was provisionally Quiet to Active geomagnetic activity, with a peak of Kp '4+' seen in the 21-24UTC interval.

Energetic Particles / Solar Radiation: GOES16 high energy (greater than 10MeV) proton flux rose slightly to around 0.5pfu at peak (14/1500UTC) in response to the 14/0745UTC M1.4 from the northwest filament eruption. This has since reverted to resting Background levels.

GOES16 high energy (greater than 2MeV) electron flux was at Normal Background to Moderate levels, with a peak of 411pfu at 14/1555UTC. The associated 24-hour fluence was well below the Active threshold, with 6.2e6 integrated pfu observed at 15/0001UTC.

Four-Day Space Weather Forecast Summary

Solar Activity: There is a daily Chance of M-class flares, mainly from AR3429 near centre-disc. The large but fading AR3423 should leave the Earth-facing side over the coming UTC weekend, but the flare risk may be maintained by the return of Ex-AR3413 in the east, which may be the source for some large recent far-sided CMEs and, by inference, large flares.

Solar Wind / Geomagnetic Activity: The geomagnetic forecast is of lower than average confidence, for a full discussion please see the Geomagnetic Storms section.

The main forecast elements are the 14/0745UTC CME (especially), and to a lesser extent the 14/2126UTC CME. An initial Slight Chance of G1 from the 11 September CME and CH47/- will give way to a Chance of G2 later in the UTC day of Saturday 16 September, bleeding into Sunday. From here, a further Chance of G1 from the 14/2126UTC CME follows on Monday 18 September.

Energetic Particles / Solar Radiation: High energy (greater than 10 MeV) proton flux is expected to remain at Background levels, with a Slight Chance of an enhancement should any larger flares occur.

High energy (greater than 2 MeV) electron flux is likely to be suppressed at Normal Background

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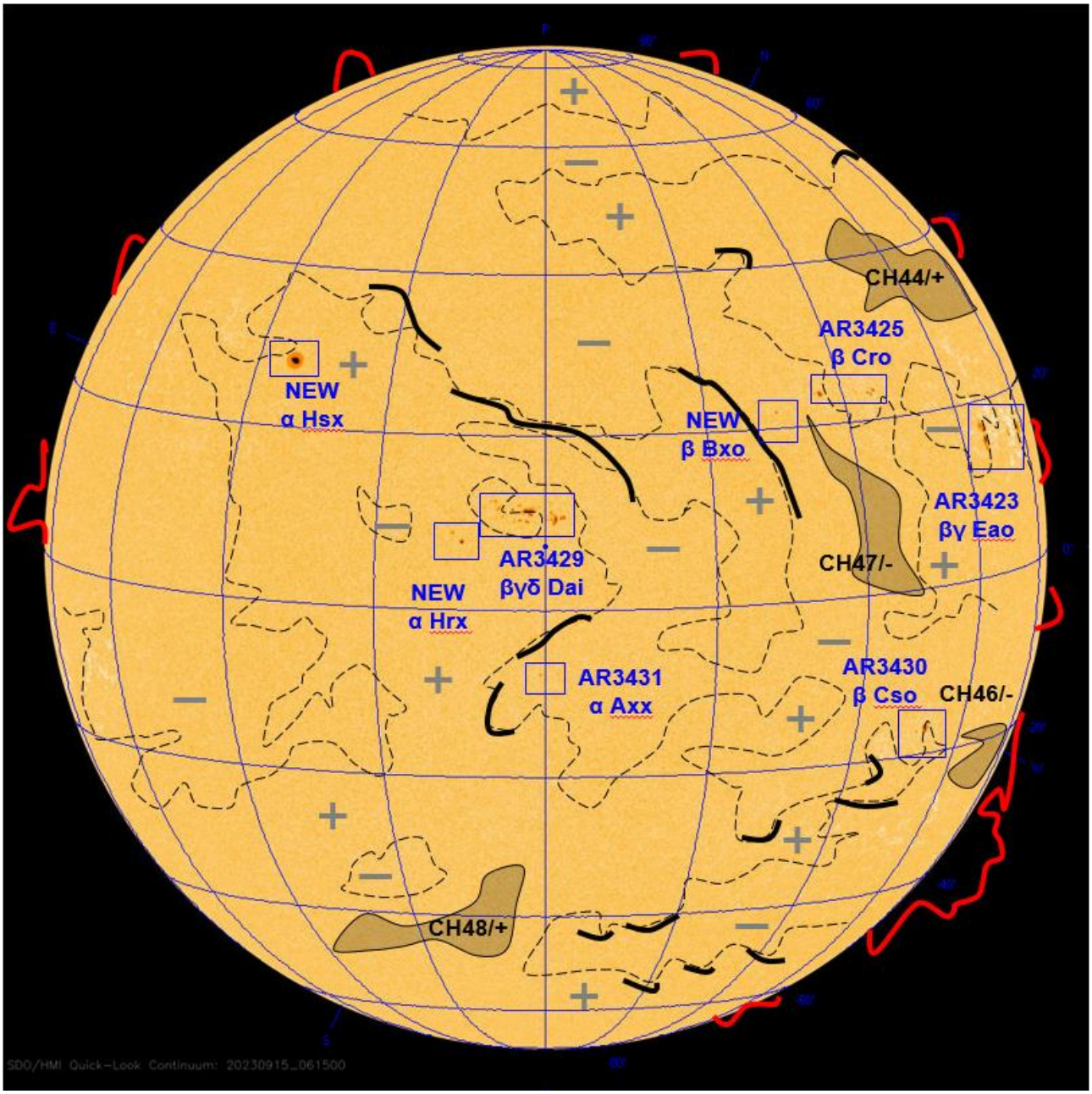
levels at GEO through much of the period, but perhaps with an eventual increase in the wake of CH47/-, now rendered lower confidence by intervening CMEs. Overall, the 24-hour fluence is Expected to remain below the Active threshold throughout the period, with reducing confidence into the new UTC week.

Figure 1. Solar Analysis Valid 15/0615UTC.



Key: Filament ___ , Prominence ___ , Magnetic Field Line - - - , Polarity +/-, Coronal Holes: Grey shaded area CHxx +/-, Sunspot groups 25xx - Mt Wilson α-β-βγ-βγδ and Zurich-McIntosh Axx etc.

Geomagnetic Storms:

The geomagnetic forecast has become more complex in the last 24 hours. The fast wind from

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CH44/+ has not materialised as forecast, with the most likely course of events now being that Earth has seen glancing influence from its CIR in the last day, and this is now waning. Its succeeding coronal hole, CH47/-, is perhaps more likely to connect for lying near the solar equator, although being of negative polarity and only having attained Kp3 on last pass, it is not likely to be significantly impactful.

This then leaves the more complex CME forecast. There are up to three that now feature. A fourth (14/2100UTC northwest filament) is awaiting further imagery for analysis.

The first CME resulted from a filament eruption in the south-centre disc around 11/1400UTC. This gave a CME which appeared slow, largely southward-directed and relatively faint in imagery. Analysis has shown that this may give Earth a weak glancing blow in the next 24 hours. Overall, little effect on geomagnetic activity is expected from this CME - if it arrives at Earth.

The second CME was from a large filament eruption in the northwest, associated with an M1.4 flare near AR3423 around 14/0745UTC. This feature was mainly directed north and west of the Sun-Earth line, however a partial halo shock (at least) was observed, and there is a reasonable chance of the edge of the main CME may impinge on Earth. Confidence in the analysis itself is low due to the single perspective available at present (L1), however it has been rendered lower still by MOSWOC Enlil's relatively poor grasp of antecedent conditions - the model had signalled a 500km/s+ fast wind for two days prior to the eruption, and brought them down as CH44/+ and CH47/- were expected to affect Earth in turn. It is partly for this reason that the arrival time of the M1.4 CME has been adjusted to 16/1800UTC rather than the modelled 16/2200UTC, which is on the advanced end of ensemble solutions. This is perhaps now on the more pessimistic side of arrival time estimates, given the very short duration of CH44's CIR to 500km/s, when a more sustained speed was envisaged.

The third and final CME was likely associated with an M2.4 flare from AR3229 at 14/2126UTC, although imagery for this event is scant. Although the flare was narrowly in the northeastern quadrant, the CME appears to be directed slightly south and east, with consensus opinion suggesting possible arrival around 18/0900UTC, although this is somewhat dependent on its precursor(s) and how they modify the interplanetary environment.

All considered, the geomagnetic forecast is of lower than average confidence. The main forecast elements are the 14/0745UTC CME (especially), and to a lesser extent the 14/2126UTC CME. An initial Slight Chance of G1 from the 11 September CME and CH47/- will give way to a Chance of G2 later in the UTC day of Saturday 16 September, bleeding into Sunday. From here, a further Chance of G1 from the 14/2126UTC CME follows on Monday 18 September.

Geo-Magnetic Storm Probability (Exceedance)	**Level**	**Past 24 Hours (Yes/No)**	**Day 1 (00-24 UTC) (%)**	**Day 2 (00-24 UTC) (%)**	**Day 3 (00-24 UTC) (%)**	**Day 4 (00-24 UTC) (%)**
Minor or Moderate	**G1 to G2**	No	10	60	40	50
Strong	**G3**	No	1	10	10	1
Severe	**G4**	No	1	1	1	1
Extreme	**G5**	No	1	1	1	1

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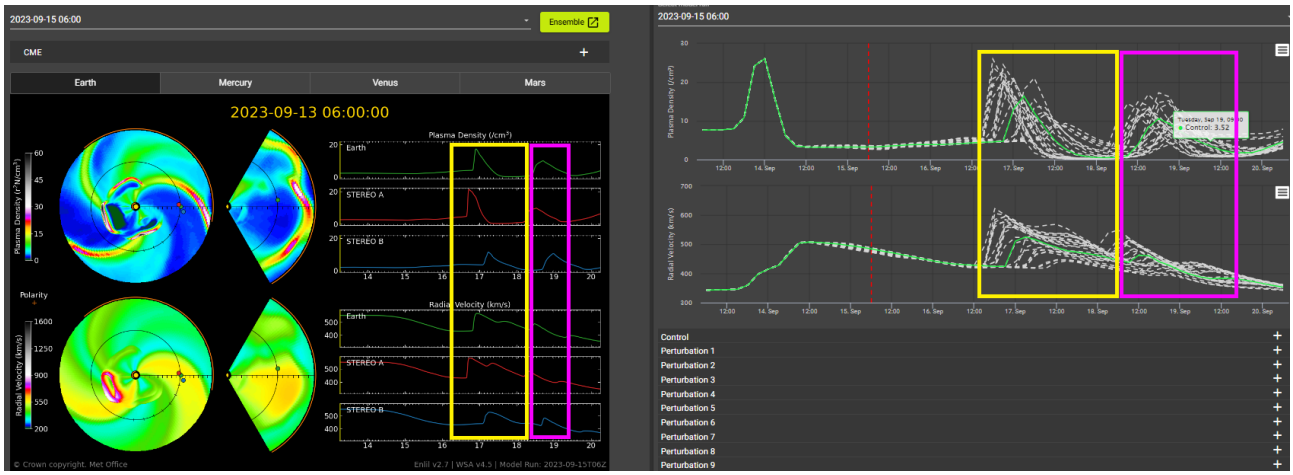
Geomagnetic Activity - Earthbound Coronal Mass Ejections

Date/time 21.5R (UTC)	Halo: Full or Partial	Source	Source Location	Estimated Speed	Estimated Arrival Time	Comments
11/0209	Partial	Filament eruption	SE	450km/s	15/1800+/-9h	Limited shock. Low confidence on arrival.
14/1159	Partial	Filament eruption	NW, near AR3423	830km/s	16/1800UTC	Arrival adjusted forwards due to model background deficiencies. Reasonable chance of hit.
15/0600	Partial	AR3429	M2.4 flare	500km/s	18/0900UTC	Edge hit. Low confidence.

Figure 2: 14/0600UTC MOSWOC Enlil run and ensemble, showing boxed yellow the 14/0745UTC M1.4 CME as arriving later in the UTC day of Saturday 16 September. Also shown is the 14/2124UTC M2.4 AR3429 CME boxed magenta. On this scale, any glance from the 11 September CME barely registers. This run does not yet feature any input from the 14/2130UTC northwest filament. Note also the poor solar wind speed shown 13-14 September – solidly 550km/s throughout, with a decline then shown to 450, almost the opposite of expectations, lowering forecast confidence.



Radio Blackouts - X-Ray Flares:

The focus of attention is now shifting from the decaying and relatively far westward AR3423, to the growing and much more centrally-located AR3429. So, while the gradual areal decay of all the bipolar groups except AR3429 in the last 24 hours has meant that the whole disc probability has fallen, it is maintained at its previous level due to observations and the presence of a Mt Wilson delta (with the raw disc figure derived from Zurich class).

In terms of the forecast, AR3423 is expected to rotate off the visible disc over the UTC weekend, however, far-side sounding data suggests that a large region is expected to rotate over the eastern horizon to mitigate against any otherwise declining risk. This arriving region is expected to be the returning Ex-AR3413, which was responsible for numerous M-class flares when last on the visible disc. A number of large, far-sided CMEs can likely be attributed to the region in the past several days, suggesting it is still active and has survived its transit of the far side.

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X Ray Flares Probability	Level	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	R1-R2 M Class	Yes	50	50	50	50
Very Active	R3 to R5 X Class	No	5	5	5	5

Figure 3: SIDC ROB-derived sources of C-class flares and above in the past 24 hours, showing that the most active spot accolade has definitely passed from AR3423 (far right) to AR3429 (centre).

Solar Radiation Storms - (High Energy Protons):

The high energy (greater than 10MeV) proton flux observed by GOES16 is expected to persist at Background levels. There remains a daily Slight Chance of flux levels rising in response to any significant flaring, with the focus now moving from AR3423 (currently near the western limb) to central AR3429 towards the end of the forecast period.

Radiation Storms Probability (Exceedance)	Level (cm^{-2} sr^{-1} s^{-1})	Past 24 Hours (Yes/No)	Day 1 (00-24 UTC) (%)	Day 2 (00-24 UTC) (%)	Day 3 (00-24 UTC) (%)	Day 4 (00-24 UTC) (%)
Active	≥ S1	No	10	10	10	10
Very Active	≥ S3 *	No	1	1	1	1
* S3 ≥ 10 MeV ≥ 1000 pfu and / or ≥ 50 MeV ≥ 10 pfu. (pfu = $cm^{-2}sr^{-1}s^{-1}$)						

Figure 4: GOES 16 high energy proton flux and X-rays, showing delayed slight response to the M1.4 of 14/0745UTC – since decayed.

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High Energy Electrons Event (≥ 2MeV):

High energy (greater than 2MeV) electron flux levels are now lower confidence than in recent guidance due to the presence of potentially Earth-directed CMEs, as well as the lack of any fully-fledged high speed stream from CH44/+. CH44/+ may now have missed Earth narrowly to the north of the ecliptic plane, with Earth perhaps instead skirting its associated southern-delimiting CIR.

Being nearer the solar equatorial plane, CH47/- is a more assured feature for connection, perhaps coming within the current UTC day. Even if Strong solar winds are seen as on last pass with this feature, the fact that these did not result in Active fluence perhaps increases confidence in their remaining below threshold, even with the complicating CME influence from later in the coming UTC weekend.

GEO Electron Environment	**Level (cm^{-2} sr^{-1} day^{-1})**	**Past 24 Hours (Yes/No)**	**Day 1 (00-24 UTC)**	**Day 2 (00-24 UTC)**	**Day 3 (00-24 UTC)**	**Day 4 (00-24 UTC)**
Probability (Exceedance)			**(%)**	**(%)**	**(%)**	**(%)**
Active	**≥ 2 MeV ≥ $1x10^8$**	No	1	1	10	20
Very Active	**≥ 2 MeV ≥ $1x10^9$**	No	1	1	1	1

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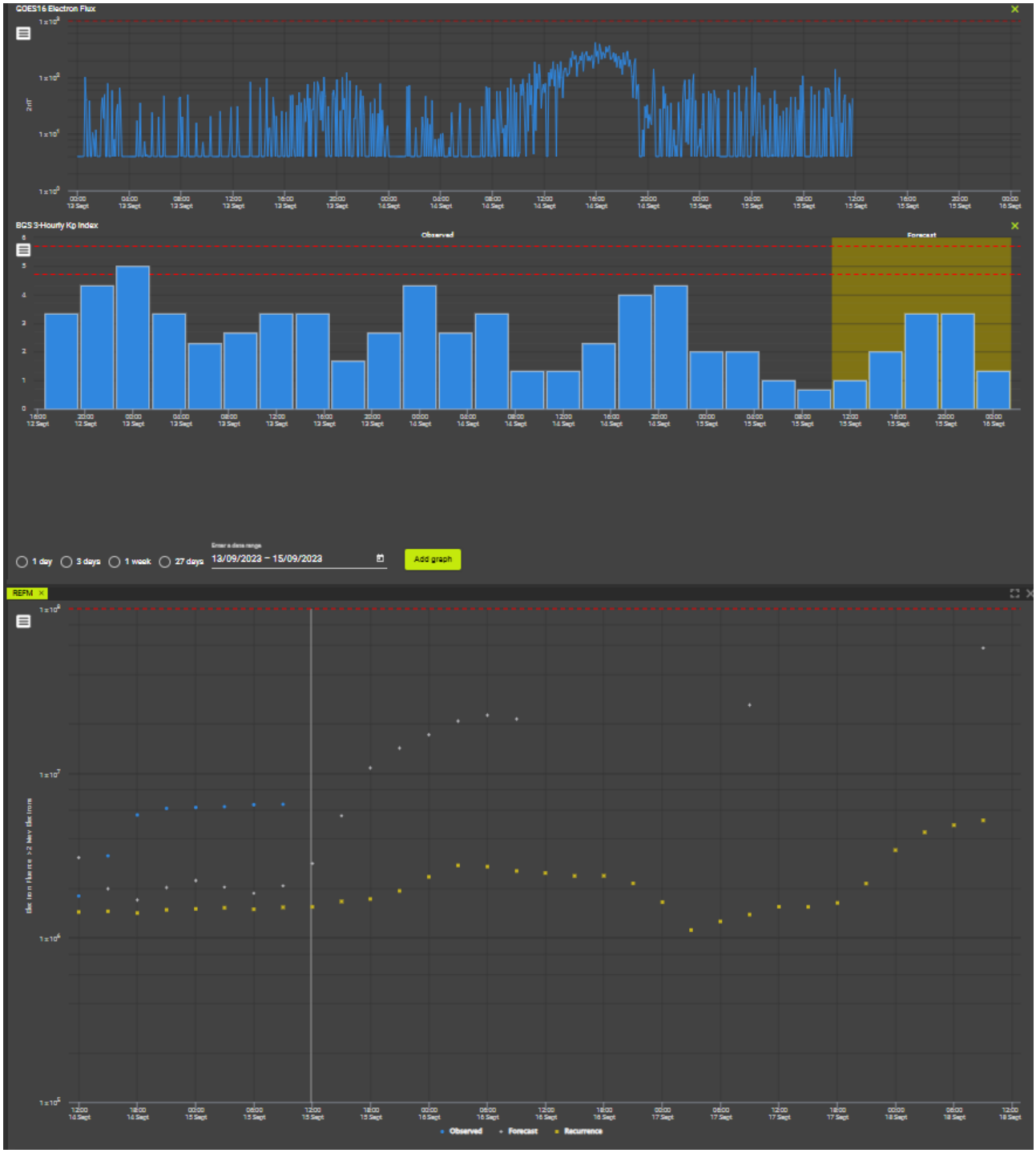
Figure 5: Past three days in GOES16 electron flux; BGS Kp geomagnetic activity, showing fall at GEO in wake of Kp4s seen overnight. The latest REFM shows a forecast rise, however CME influence renders this low confidence.



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